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Nakamura et al.

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(54) **CONTROL OF BASE STATION PARAMETERS BASED ON MAPPING OF TERMINAL DISTRIBUTION**

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(22) Filed: **Jan. 31, 2014**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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H04W 24/02	(2009.01)
H04W 28/00	(2009.01)
H04W 52/24	(2009.01)
H04W 52/14	(2009.01)
H04W 52/22	(2009.01)
H04W 72/04	(2009.01)
H04W 16/22	(2009.01)
H04W 52/28	(2009.01)
H04W 28/18	(2009.01)
H04W 4/02	(2009.01)
H04W 4/08	(2009.01)

(52) **U.S. Cl.**

CPC ***H04W 52/241*** (2013.01); ***H04W 16/22*** (2013.01); ***H04W 52/143*** (2013.01); ***H04W 52/225*** (2013.01); ***H04W 52/228*** (2013.01); ***H04W 52/245*** (2013.01); ***H04W 72/0453*** (2013.01); *H04W 4/023* (2013.01); *H04W 4/08* (2013.01); *H04W 28/18* (2013.01); *H04W 52/283* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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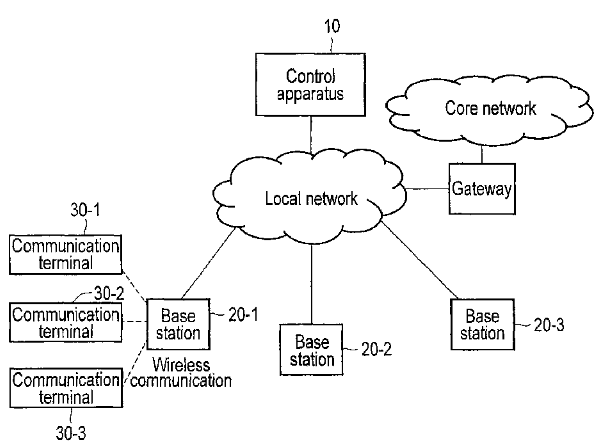
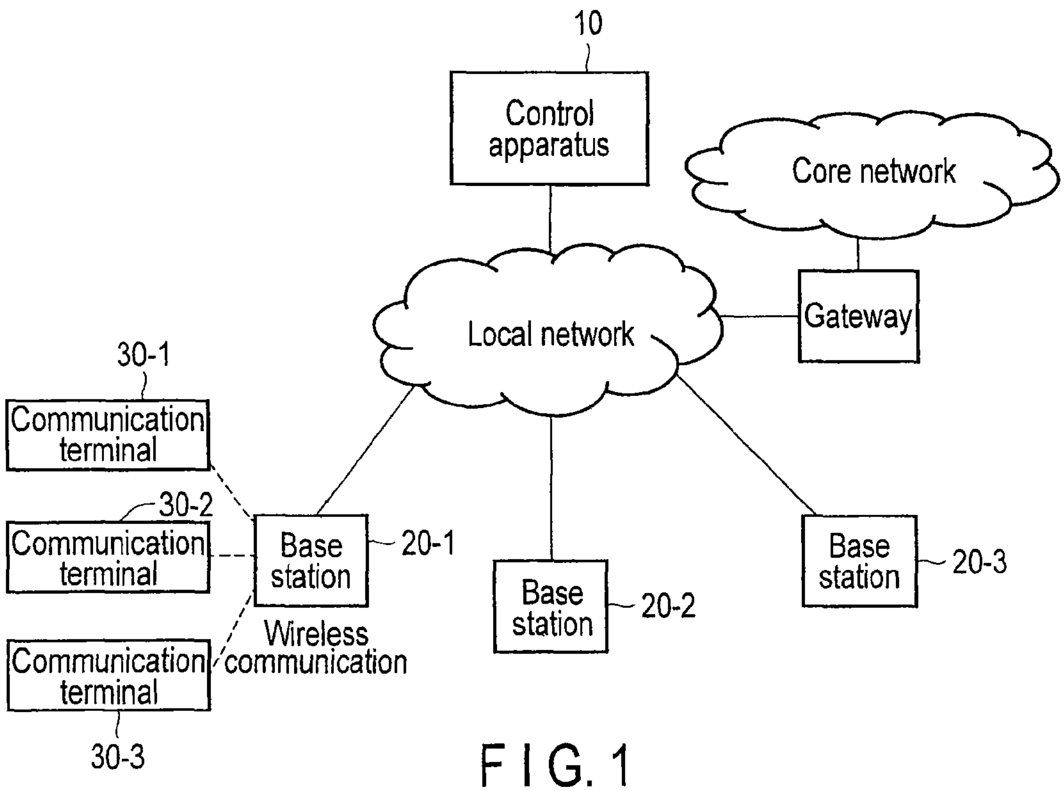
(57) **ABSTRACT**

According to one embodiment, a control apparatus includes a terminal information collection unit, a map generator, a terminal information accumulation unit, a parameter calculator, and a parameter setting unit. A map generator generates a map indicating a distribution of the representative terminals. A terminal information accumulation unit accumulates the map generated by the map generator. A parameter calculator sets operating frequencies and transmission powers for the base stations by simulation, empirically estimate, based on past maps accumulated in the terminal information accumulation unit, received powers of the representative terminals generated by the operating frequencies and transmission powers sets by simulation, and determine new operating frequencies.

8 Claims, 13 Drawing Sheets

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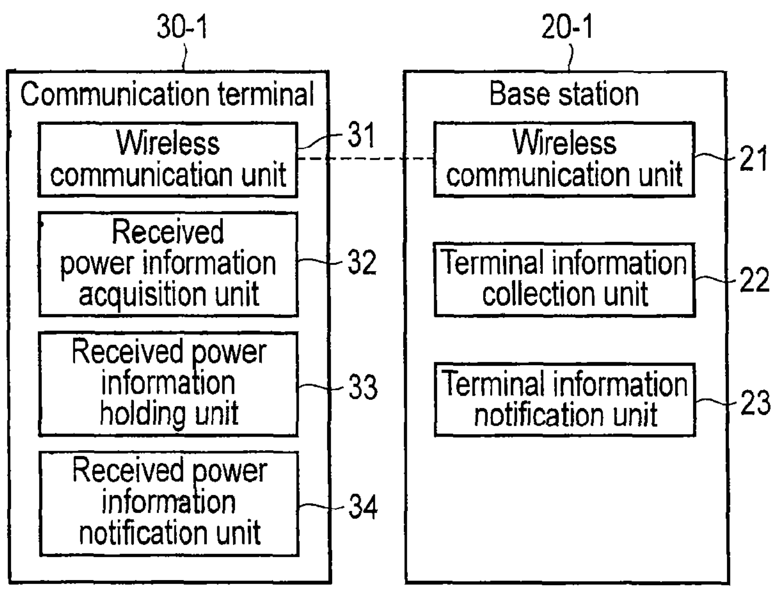
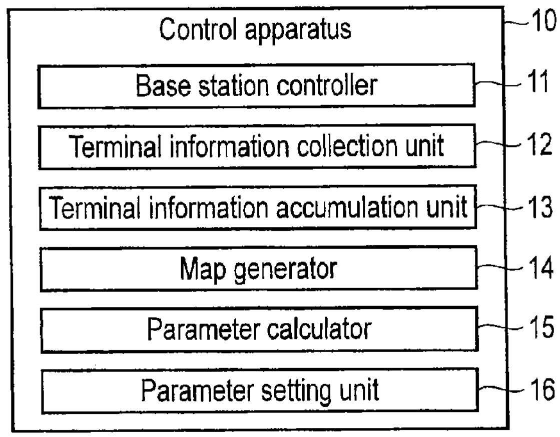
Control apparatus
Core network
Local network
Gateway
30-1
Communication terminal
30-2
Communication terminal
Base station
20-1
Base station
20-2
Base station
20-3
Wireless communication
Communication terminal
30-3

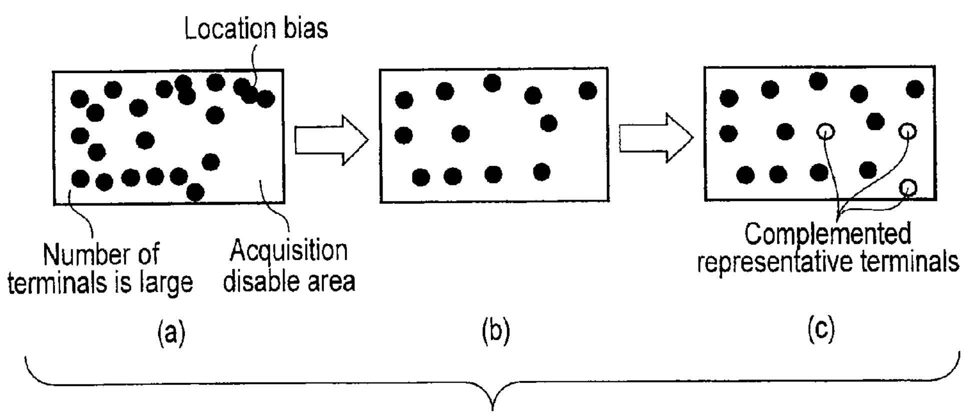
F I G. 1


30-1
20-1
Communication terminal
Base station
Wireless communication unit
31
Wireless communication unit
21
Received power information acquisition unit
32
Terminal information collection unit
22
Received power information holding unit
33
Terminal information notification unit
23
Received power information notification unit
34

F I G. 2


Control apparatus
10
Base station controller
11
Terminal information collection unit
12
Terminal information accumulation unit
13
Map generator
14
Parameter calculator
15
Parameter setting unit
16

F I G. 3


Location bias
Number of terminals is large
Acquisition disable area
Complemented representative terminals
(a)
(b)
(c)

F I G. 4

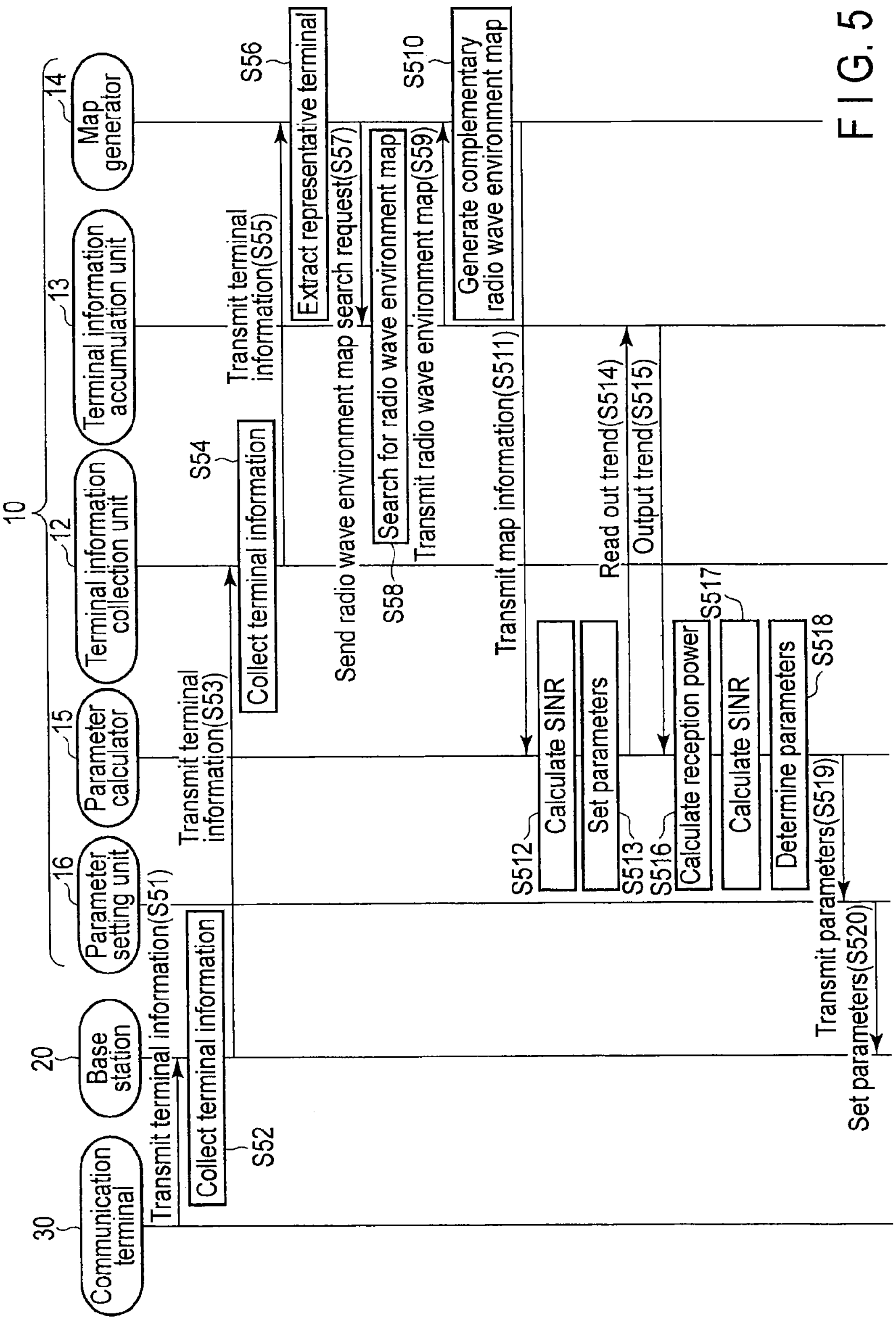

10
30
Communication terminal
20
Base station
16
Parameter setting unit
15
Parameter calculator
12
Terminal information collection unit
13
Terminal information accumulation unit
14
Map generator
Transmit terminal information(S51)
Collect terminal information
S52
Transmit terminal information(S53)
Collect terminal information
S54
Transmit terminal information(S55)
Extract representative terminal
S56
Send radio wave environment map search request(S57)
Search for radio wave environment map
S58
Transmit radio wave environment map(S59)
Generate complementary radio wave environment map
S510
Transmit map information(S511)
Calculate SINR
S512
Set parameters
S513
Read out trend(S514)
Output trend(S515)
Calculate reception power
S516
Calculate SINR
S517
Determine parameters
S518
Transmit parameters(S519)
Transmit parameters(S520)
Set parameters

FIG. 5

Physical cell ID	Received power
100	-70dBm
107	-75dBm

FIG. 6

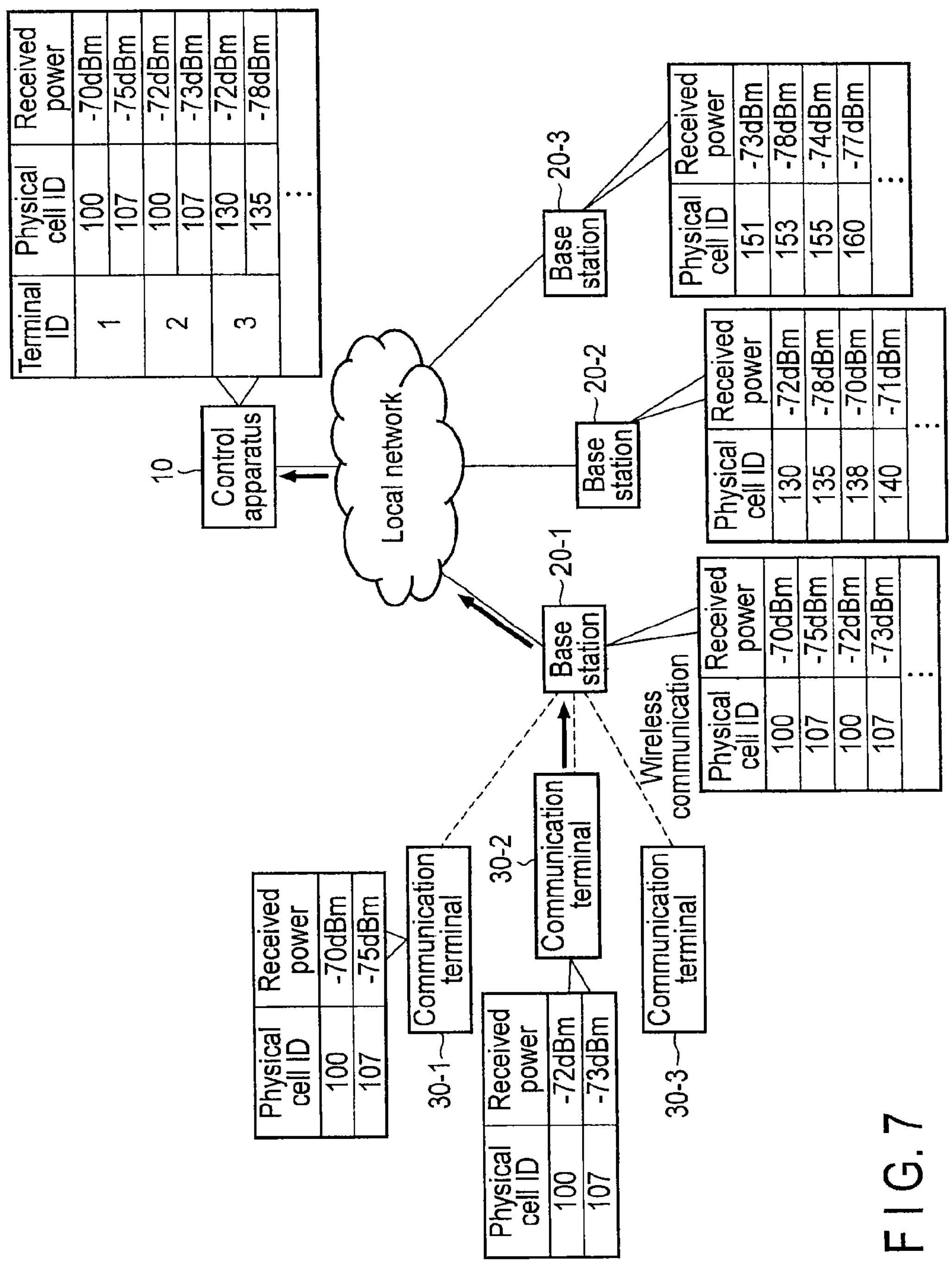

10
Control apparatus
Terminal ID
Physical cell ID
Received power
1
100
-70dBm
107
-75dBm
2
100
-72dBm
107
-73dBm
3
130
-72dBm
135
-78dBm
Local network
20-1
Base station
20-2
Base station
20-3
Base station
Physical cell ID
Received power
100
-70dBm
107
-75dBm
100
-72dBm
107
-73dBm
130
-72dBm
135
-78dBm
138
-70dBm
140
-71dBm
151
-73dBm
153
-78dBm
155
-74dBm
160
-77dBm
Wireless communication
30-1
30-2
30-3
Communication terminal
Physical cell ID
Received power
100
-70dBm
107
-75dBm
100
-72dBm
107
-73dBm

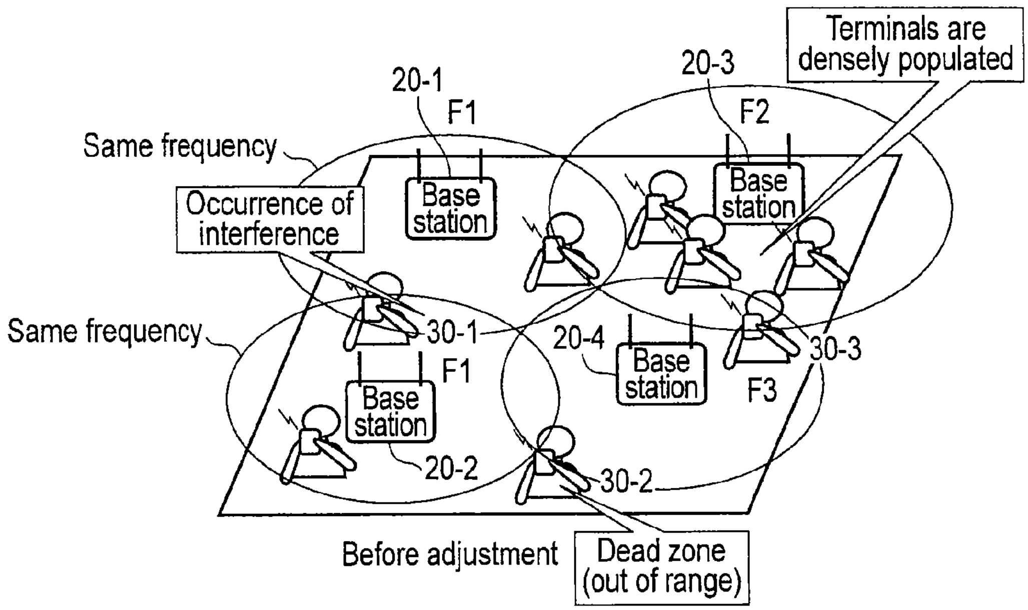
FIG. 7

Representative terminal	Base station1		Base station2		Base station3		Number of communication terminals in group
	Operating frequency/ transmission power	Received power	Operating frequency/ transmission power	Received power	Operating frequency/ transmission power	Received power	
1	F1/100mW	-72dBm	F1/100mW	-82dBm	F1/100mW	-74dBm	5
2	F1/100mW	-80dBm	F1/100mW	-76dBm	F1/100mW	-73dBm	2
...							
100	F1/100mW	-75dBm	F1/100mW	-80dBm	F1/100mW	-70dBm	3

F I G. 8

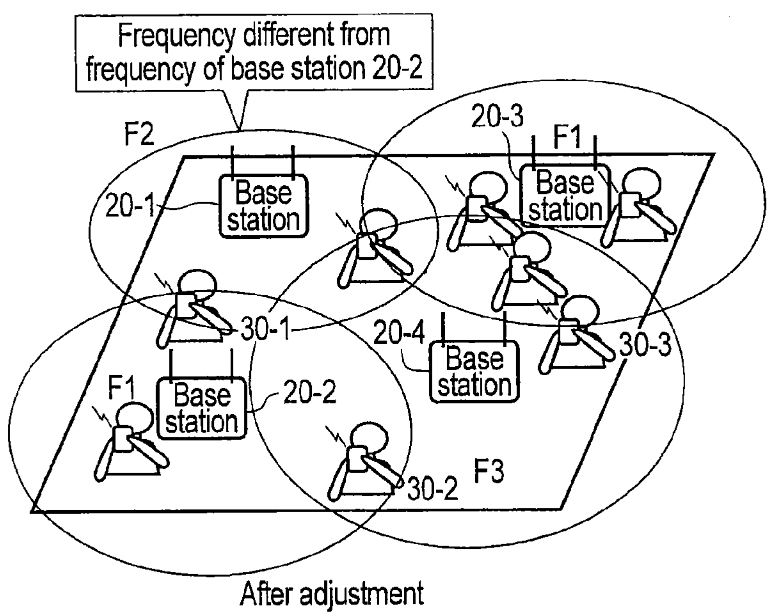
Pattern	Representative terminal	Base station1		Base station2		Base station3		Number of communication terminals in group	SINR value	Lowest SINR value	Average SINR value	Highest SINR value
		Operating frequency/transmission power	Received power	Operating frequency/transmission power	Received power	Operating frequency/transmission power	Received power					
1	1	F1/100mW	-72dBm	F1/100mW	-82dBm	F1/100mW	-74dBm	5	1dBm	1dBm	19dBm	37dBm
	2	F1/100mW	-80dBm	F1/100mW	-76dBm	F1/100mW	-73dBm	2	2dBm			
	⋮											
	100	F1/100mW	-75dBm	F1/100mW	-80dBm	F1/100mW	-70dBm	3	4dBm			
2	1	F1/100mW	-72dBm	F1/100mW	-82dBm	F1/50mW	-77dBm	2	4dBm	-1dBm	17dBm	35dBm
	2	F1/100mW	-80dBm	F1/100mW	-76dBm	F1/50mW	-76dBm	4	-1dBm			
	⋮											
	100	F1/100mW	-75dBm	F1/100mW	-80dBm	F1/50mW	-76dBm	1	1dBm			
⋮												
729	1	F3/10mW	-82dBm	F3/10mW	-92dBm	F3/10mW	-84dBm	2	1dBm	1dBm	16dBm	31dBm
	2	F3/10mW	-90dBm	F3/10mW	-86dBm	F3/10mW	-83dBm	2	1dBm			
	⋮											
	100	F3/10mW	-85dBm	F3/10mW	-90dBm	F3/10mW	-80dBm	1	4dBm			

F I G. 9



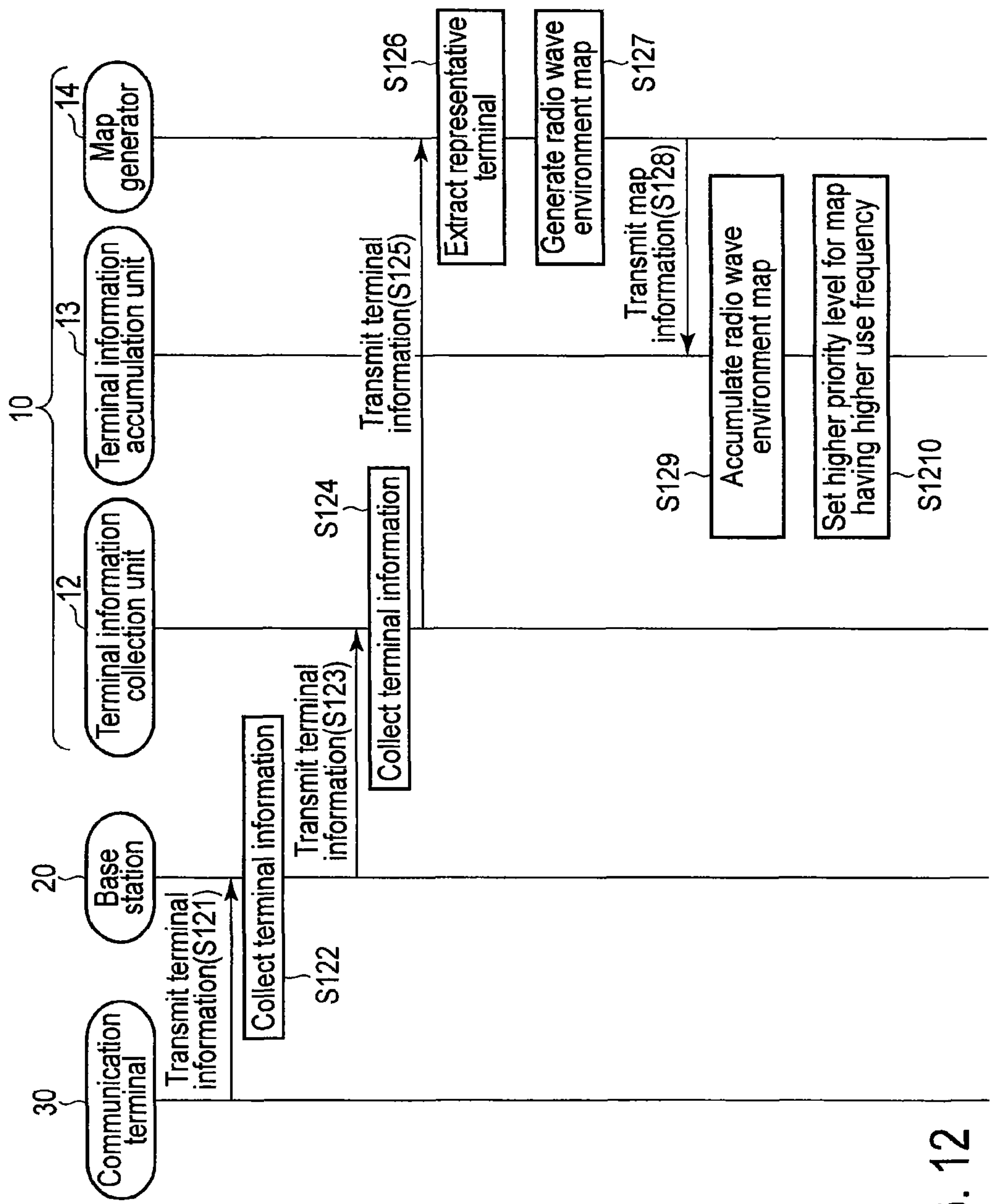
Terminals are densely populated
20-1
F1
20-3
F2
Same frequency
Base station
Occurrence of interference
Base station
Same frequency
30-1
20-4
Base station
30-3
F1
Base station
F3
20-2
30-2
Before adjustment
Dead zone (out of range)

F I G. 10



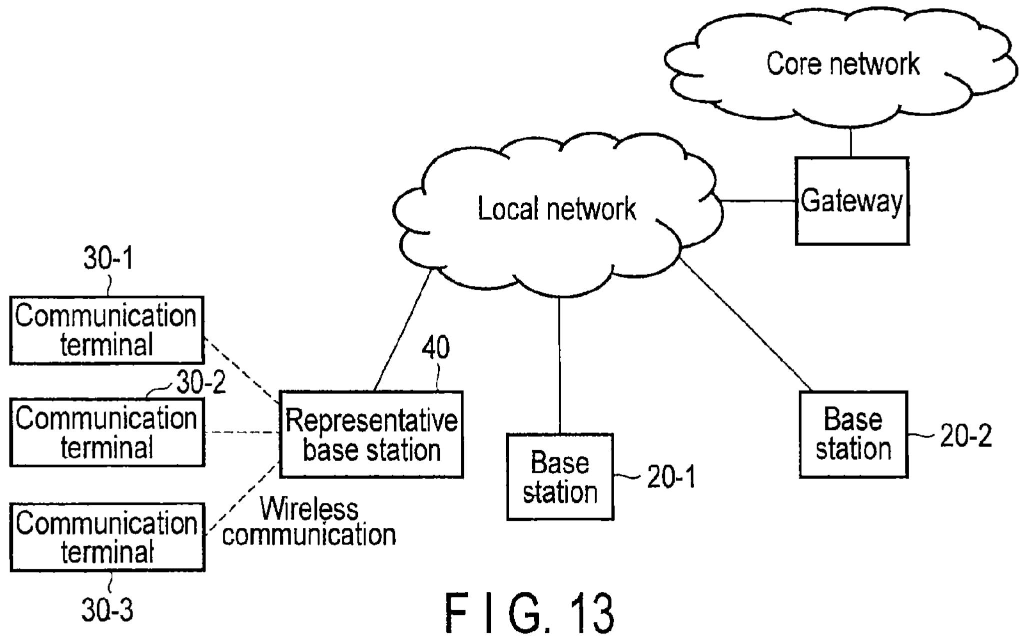
Frequency different from frequency of base station 20-2
F2
20-3
F1
20-1
Base station
Base station
30-1
20-4
30-3
F1
Base station
20-2
Base station
30-2
F3
After adjustment

F I G. 11

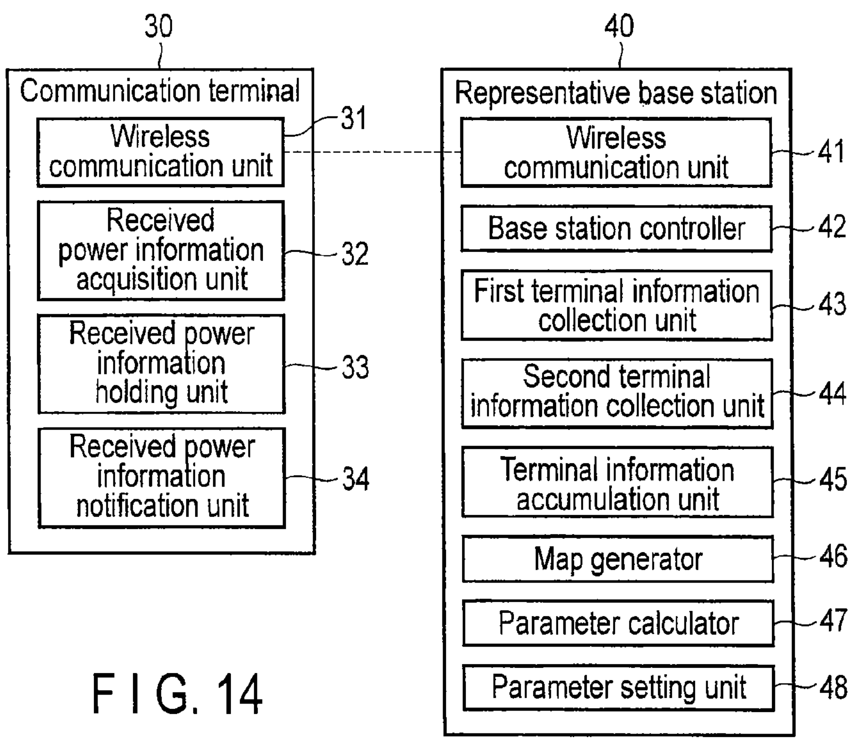


10
30
Communication terminal
20
Base station
12
Terminal information collection unit
13
Terminal information accumulation unit
14
Map generator
Transmit terminal information(S121)
Collect terminal information
S122
Transmit terminal information(S123)
Collect terminal information
S124
Transmit terminal information(S125)
Extract representative terminal
S126
Generate radio wave environment map
S127
Transmit map information(S128)
Accumulate radio wave environment map
S129
Set higher priority level for map having higher use frequency
S1210

F I G. 12


Core network
Local network
Gateway
30-1
Communication terminal
30-2
Communication terminal
Representative base station
40
Base station
20-1
Base station
20-2
Communication terminal
30-3
Wireless communication

F I G. 13


30
Communication terminal
Wireless communication unit
31
Received power information acquisition unit
32
Received power information holding unit
33
Received power information notification unit
34
40
Representative base station
Wireless communication unit
41
Base station controller
42
First terminal information collection unit
43
Second terminal information collection unit
44
Terminal information accumulation unit
45
Map generator
46
Parameter calculator
47
Parameter setting unit
48

F I G. 14

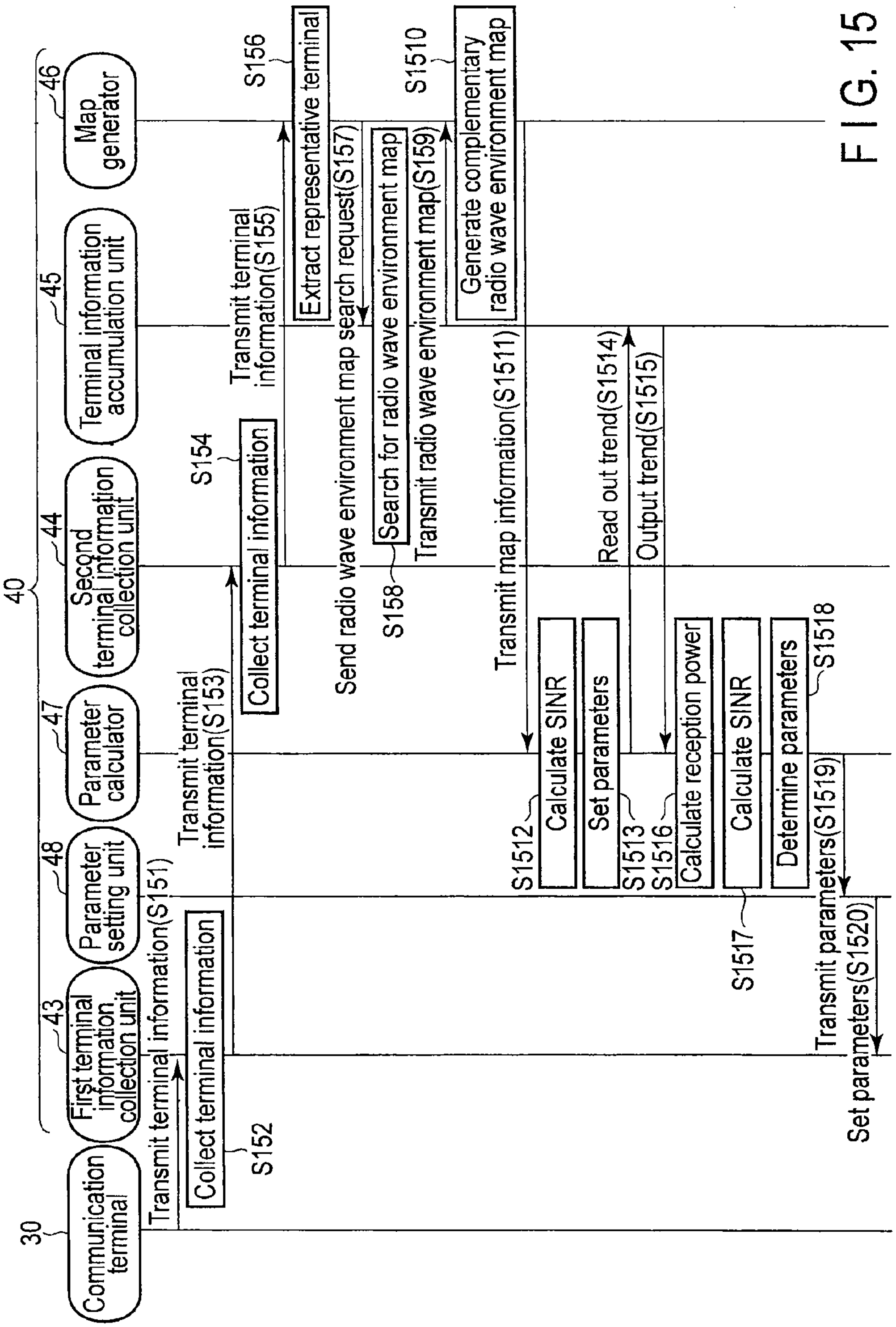
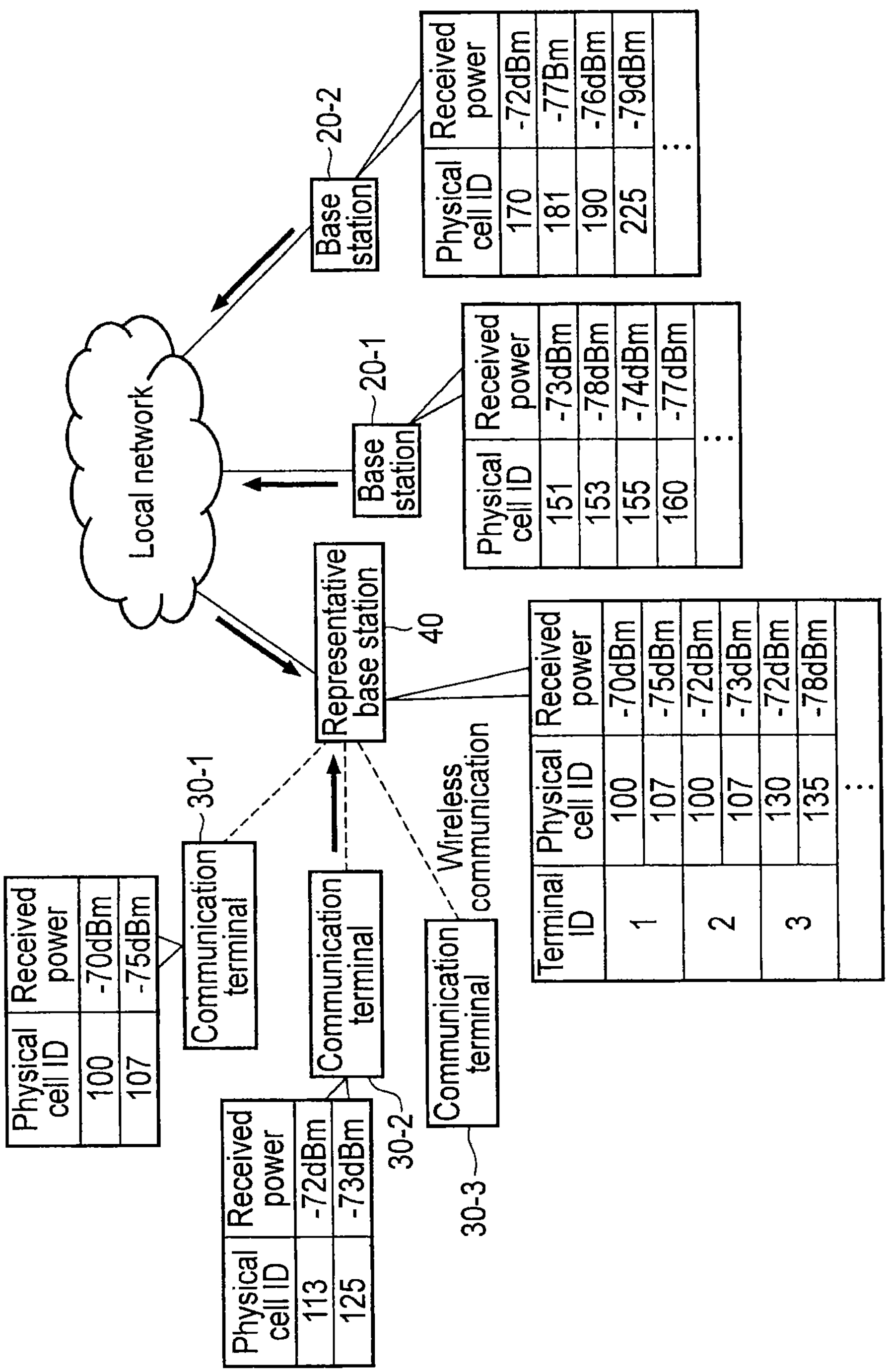
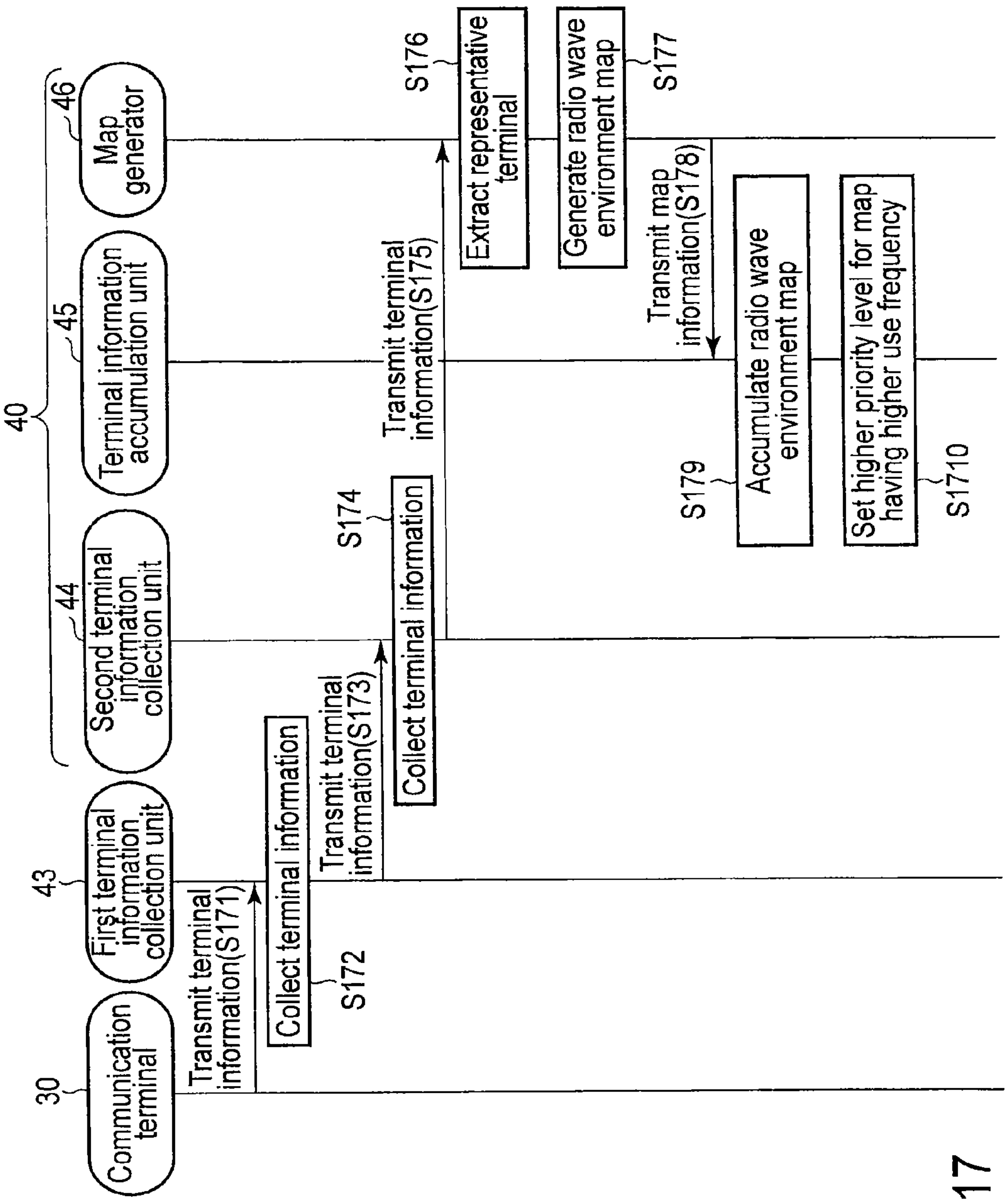

40
30 Communication terminal
43 First terminal information collection unit
48 Parameter setting unit
47 Parameter calculator
44 Second terminal information collection unit
45 Terminal information accumulation unit
46 Map generator
Transmit terminal information(S151)
S152 Collect terminal information
Transmit terminal information(S153)
S154 Collect terminal information
Transmit terminal information(S155)
S156 Extract representative terminal
Send radio wave environment map search request(S157)
S158 Search for radio wave environment map
Transmit radio wave environment map(S159)
S1510 Generate complementary radio wave environment map
Transmit map information(S1511)
S1512 Calculate SINR
S1513 Set parameters
Read out trend(S1514)
Output trend(S1515)
S1516 Calculate reception power
S1517 Calculate SINR
S1518 Determine parameters
Transmit parameters(S1519)
Transmit parameters(S1520)
Set parameters

FIG. 15



Local network
Base station
20-2
Physical cell ID
Received power
170
-72dBm
181
-77Bm
190
-76dBm
225
-79dBm
Base station
20-1
Physical cell ID
Received power
151
-73dBm
153
-78dBm
155
-74dBm
160
-77dBm
Representative base station
40
Terminal ID
Physical cell ID
Received power
1
100
-70dBm
107
-75dBm
2
100
-72dBm
107
-73dBm
3
130
-72dBm
135
-78dBm
Communication terminal
30-1
Physical cell ID
Received power
100
-70dBm
107
-75dBm
Communication terminal
30-2
Physical cell ID
Received power
113
-72dBm
125
-73dBm
Communication terminal
30-3
Wireless communication

FIG. 16


30
Communication terminal
43
First terminal information collection unit
40
44
Second terminal information collection unit
45
Terminal information accumulation unit
46
Map generator
Transmit terminal information(S171)
Collect terminal information
S172
Transmit terminal information(S173)
Collect terminal information
S174
Transmit terminal information(S175)
Extract representative terminal
S176
Generate radio wave environment map
S177
Transmit map information(S178)
Accumulate radio wave environment map
S179
Set higher priority level for map having higher use frequency
S1710

F I G. 17

CONTROL OF BASE STATION PARAMETERS BASED ON MAPPING OF TERMINAL DISTRIBUTION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from the prior Japanese Patent Applications No. 2013-051570, filed Mar. 14, 2013, the entire which are incorporated herein by reference.

FIELD

Embodiments described herein relate to a control apparatus and a representative base station which are used in a wireless communication system for wirelessly communicating with a communication terminal using a local network, and a base station control method used in the wireless communication system.

BACKGROUND

Mobile traffic is increasing year by year, and it is thus desired to increase the speed of mobile communication. Meanwhile, each telecommunications carrier has started an LTE (Long Term Evolution) service for high-speed wireless communication. On the other hand, indoor mobile traffic is also increasing year by year. Along with an increase in mobile data traffic, it is required to improve the wireless quality of indoor traffic.

To increase an indoor traffic capacity, it is necessary to arrange a number of base stations called femtocells each having a radio radius of about several tens of meters in a close range. When base stations of the same operating frequency are adjacent to each other, interference occurs, thereby decreasing the throughput. To improve the wireless quality of indoor traffic, it is necessary to eliminate an indoor dead zone by adjusting the transmission powers of the femtocells, and suppress interference by assigning operating frequencies to the femtocells so that the coverage areas of the femtocells of the same operating frequency do not overlap each other, thereby improving the throughput.

Conventionally, there has been adopted a method of generating a radio wave environment map for recognizing an indoor radio wave environment using a measurement terminal, and setting optimal parameters for each base station based on the map. In the method, however, when the radio wave environment changes, it is impossible to maintain the optimal radio wave environment. For example, in the method, every time the indoor operation environment changes after the start of the operation of base stations (for example, an indoor base station is newly added, an indoor base station fails, and an indoor layout changes due to movement of a wall), an examiner needs to measure the radio wave environment again using the measurement terminal, thereby decreasing the throughput.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing the arrangement of a wireless communication system according to the first embodiment;

FIG. **2** is a block diagram showing the functional arrangement of a base station and communication terminal, both shown in FIG. **1**;

FIG. **3** is a block diagram showing the functional arrangement of a control apparatus shown in FIG. **1**;

FIG. **4** is a view showing a procedure of generating a complementary radio wave environment map from terminal information collected in the control apparatus shown in FIG. **1**;

FIG. **5** is a sequence chart when the wireless communication system shown in FIG. **1** sets base station parameters;

FIG. **6** is a table schematically showing an example of a correspondence table transmitted from the communication terminal to the base station, both shown in FIG. **1**;

FIG. **7** is a schematic view showing an example of correspondence tables in the communication terminals, base stations, and control apparatus which are shown in FIG. **1**;

FIG. **8** is a table showing a radio wave environment map generated by a map generator of the control apparatus shown in FIG. **1**;

FIG. **9** is a table schematically showing the received power and SINR of each representative terminal when base station parameters change, which are calculated by a parameter calculator of the control apparatus shown in FIG. **3**;

FIG. **10** is a schematic view showing an example of a state before the control apparatus shown in FIG. **1** adjusts base stations;

FIG. **11** is a schematic view showing an example of a state after the control apparatus shown in FIG. **1** adjusts the base stations;

FIG. **12** is a sequence chart showing a procedure in which a terminal information accumulation unit of the control apparatus shown in FIG. **3** accumulates a radio wave environment map;

FIG. **13** is a block diagram showing the functional arrangement of a wireless communication system according to the second embodiment;

FIG. **14** is a block diagram showing the functional arrangement of a representative base station and communication terminal, both shown in FIG. **13**;

FIG. **15** is a sequence chart when the wireless communication system shown in FIG. **13** sets parameters in the representative base station and base stations;

FIG. **16** is a schematic view showing an example of correspondence tables in the communication terminals, representative base station, and base stations which are shown in FIG. **13**; and

FIG. **17** is a sequence chart showing a procedure in which a terminal information accumulation unit of the representative base station shown in FIG. **14** accumulates a radio wave environment map.

DETAILED DESCRIPTION

In general, according to one embodiment, a control apparatus includes a terminal information collection unit, a map generator, a terminal information accumulation unit, a parameter calculator, and a parameter setting unit. A map generator generates a map indicating a distribution of the representative terminals. A terminal information accumulation unit accumulates the map generated by the map generator. A parameter calculator sets operating frequencies and transmission powers for the base stations by simulation, empirically estimate, based on past maps accumulated in the terminal information accumulation unit, received powers of the representative terminals generated by the operating frequencies and transmission powers sets by simulation, and determine new operating frequencies.

Embodiments will be described below with reference to the accompanying drawings.

(First embodiment)

FIG. **1** is a block diagram showing the functional arrangement of a wireless communication system according to the first embodiment.

The wireless communication system shown in FIG. **1** includes a control apparatus **10** and base stations **20-1** to **20-3**. The control apparatus **10** and base stations **20-1** to **20-3** are connected to each other via a local network. Referring to FIG. **1**, the base station **20-1** accommodates communication terminals **30-1** to **30-3** for wirelessly communicating with it. Although not shown in FIG. **1**, each of the base stations **20-2** and **20-3** accommodates communication terminals for wirelessly communicating with it. The local network is connected to a core network (carrier network) via a gateway.

FIG. **2** is a block diagram showing the functional arrangement of the base station **20-1** and communication terminal **30-1**, both shown in FIG. **1**. Note that although FIG. **2** exemplifies the functional arrangement of the communication terminal **30-1** and base station **20-1**, the arrangement of the communication terminal **30-2** or **30-3** and the base station **20-2** or **20-3** is also the same as that shown in FIG. **2**.

The communication terminal **30-1** shown in FIG. **2** includes a wireless communication unit **31**, a received power information acquisition unit **32**, a received power information holding unit **33**, and a received power information notification unit **34**.

The wireless communication unit **31** wirelessly communicates with, for example, the base station **20-1** having a highest received power of a signal to be transmitted among the base stations **20-1** to **20-3** according to an LTE protocol.

The received power information acquisition unit **32** acquires the received power of a signal transmitted by each of the base stations **20-1** to **20-3**, a physical cell ID for specifying the base station which has transmitted the signal, a throughput, an error rate in communication, and sensor information such as Global Positioning System(GPS) information for specifying the position of the communication terminal at preset intervals. Note that it is possible to acquire the received power and physical cell ID in the LTE standard specification.

The received power information holding unit **33** forms and holds a correspondence table between the acquired received power and physical cell ID. The received power information holding unit **33** updates the held correspondence table every time the received power information acquisition unit **32** acquires a new received power and physical cell ID.

In response to a request from the connected base station **20-1**, the received power information notification unit **34** transmits the held correspondence table and sensor information to the base station **20-1** as terminal information. At this time, the received power information notification unit **34** transmits the terminal information added with the identifier of the self-terminal to the base station **20-1**. Note that the received power information notification unit **34** may actively transmit the terminal information to the base station **20-1** at a preset timing.

The base station **20-1** shown in FIG. **2** includes a wireless communication unit **21**, a terminal information collection unit **22**, and a terminal information notification unit **23**.

The wireless communication unit **21** wirelessly communicates with the communication terminals **30-1** to **30-3**.

The terminal information collection unit **22** receives terminal information transmitted by each of the communication terminals **30-1** to **30-3**, and collects the received terminal information together with the identifier. When requesting terminal information of the communication terminals **30-1** to **30-3**, the terminal information collection unit **22** may request terminal information of all the communication terminals **30-1** to **30-3**, or request terminal information of only communication terminals not in an idle state but in a connected state. Note that the idle state indicates a state in which communication between the base station and the communication terminal has not been performed for a predetermined period of time and thus the communication terminal has deactivated its communication function.

The terminal information notification unit **23** transmits the collected terminal information to the control apparatus **10**. Note that the terminal information notification unit **23** may transmit the terminal information to the control apparatus **10** at a preset timing.

FIG. **3** is a block diagram showing the functional arrangement of the control apparatus **10** shown in FIG. **1**.

The control apparatus **10** includes, for example, a Central Processing Unit(CPU), and areas such as a Read Only Memory(ROM) and Random Access Memory(RAM) for storing programs and data to be used by the CPU to execute processing. The control apparatus **10** includes a base station controller **11**, terminal information collection unit **12**, terminal information accumulation unit **13**, map generator **14**, parameter calculator **15**, and parameter setting unit **16**, which are shown in FIG. **3**, by causing the CPU to execute programs.

The base station controller **11** controls the operation of each of the base stations **20-1** to **20-3**.

The terminal information collection unit **12** collects terminal information transmitted by each of the base stations **20-1** to **20-3**. The terminal information collection unit **12** transmits the collected terminal information to the map generator **14**. Note that the terminal information collection unit **12** may receive terminal information from each of the base stations **20-1** to **20-3** at regular intervals, or receive terminal information by sending a terminal information acquisition request to each of the base stations **20-1** to **20-3**.

The terminal information accumulation unit **13** accumulates a radio wave environment map generated by the map generator **14**. Note that the radio wave environment map will be described in conjunction with the map generator **14**.

In response to a request from the map generator **14**, the terminal information accumulation unit **13** searches accumulated past radio wave environment maps for a radio wave environment map with the distribution of representative terminals similar to that of the radio wave environment map generated by the map generator **14**. The terminal information accumulation unit **13** transmits the radio wave environment map obtained by the search processing to the map generator **14**. Note that the representative terminals will be described in conjunction with the map generator **14**, similarly to the above radio wave environment map.

Furthermore, the terminal information accumulation unit **13** sets priority levels for the accumulated radio wave environment maps so that a radio wave environment map having a higher use frequency has a higher priority level. For example, the terminal information accumulation unit **13** accumulates, for each radio wave environment map, as an index for recognizing a use frequency, the number of times the radio wave environment map is transmitted to the map generator **14**, and then sets a higher priority level for a radio wave environment map transmitted a larger number of times.

The map generator **14** extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other. Note that "close" means that the distance between communication terminals is shorter than a predetermined one. The representative terminal includes terminal information collected when grouping the communication terminals. As a clustering method, well-known hierarchical clustering such as a group average method, single linkage method, or complete linkage method, or well-known non-hierarchical clustering such as a K-means method or EM (Expectation Maximization) algorithm may be used. When, for example, hierarchical clustering is adopted, the map generator **14** determines that communication terminals having similar terminal information are close to each other. The map generator **14** generates a radio wave environment map indicating the distribution of the representative terminals in an indoor area. The map generator **14** transmits the generated radio wave environment map to the terminal information accumulation unit **13**.

If an area where no representative terminal is extracted since no communication terminal is present and thus it is impossible to extract any terminal information, the map generator **14** complements a representative terminal in the area where no representative terminal is extracted. At this time, the map generator **14** sends a radio wave environment map search request to the terminal information accumulation unit **13**. The map generator **14** acquires one of the radio wave environment maps accumulated in the terminal information accumulation unit **13**, which has a distribution of representative terminals similar to that of the generated radio wave environment map. The map generator **14** complements, by the acquired radio wave environment map, a representative terminal in the area where no representative terminal is extracted, and generates a complementary radio wave environment map including the complemented representative terminal. The map generator **14** transmits the generated complementary radio wave environment map to the parameter calculator **15**.

FIG. **4** is a view showing a procedure of generating a complementary radio wave environment map from terminal information collected in the control apparatus **10** shown in FIG. **1**. Since there are many communication terminals as shown in (a) of FIG. **4**, the map generator **14** clusters them to extract representative terminals as shown in (b) of FIG. **4**. Furthermore, as shown in (c) of FIG. **4**, the map generator **14** acquires a radio wave environment map from the terminal information accumulation unit **13**, and complements, by the acquired radio wave environment map, a representative terminal in an area where it is impossible to extract any representative terminal.

Note that the map generator **14** may specify the position of each communication terminal based on sensor information such as GPS information transmitted from the communication terminal via the base station. At this time, the map generator **14** determines based on the pieces of position information of the communication terminals whether they are close to each other, and extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other.

Based on the complementary radio wave environment map generated by the map generator **14**, the parameter calculator **15** determines a transmission power, operating frequency, physical cell ID, neighbor list, handover threshold, base station ID, frequency bandwidth, the IP address of a base station, neighboring cell information, cell size, and the like. Note that the neighbor list, neighboring cell information, and handover threshold can form a radio wave environment in combination with the transmission power and operating frequency. That is, it is possible to control handover and generate a radio wave environment on the assumption that frequency resources are reallocated to the communication terminals in operation by intentionally changing the neighbor list and neighboring cell information in operation. Furthermore, by using the changed handover threshold, it is possible to improve the throughput by changing the connection destination of a terminal.

As a practical example, a method of determining transmission powers and operating frequencies for the base stations will be described.

The parameter calculator **15** receives the complementary radio wave environment map transmitted by the map generator **14**, and calculates an Signal to Interference and Noise power Ratio(SINR) for each representative terminal of the received complementary radio wave environment map based on terminal information included in the representative terminal. Furthermore, based on the calculated SINRs for the respective representative terminals, the parameter calculator **15** obtains the variance of the SINRs, a lowest SINR value, an average SINR value, and a highest SINR value.

The parameter calculator **15** sets operating frequencies and transmission powers for the base stations by simulation, and empirically estimates the received powers of the representative terminals for the operating frequencies and transmission powers set by simulation, based on the past maps accumulated in the terminal information accumulation unit **13**. The parameter calculator **15** determines new operating frequencies and transmission powers for the base stations based on the estimation result.

For example, the parameter calculator **15** sets base station parameters for the base stations **20-1** to **20-3** by simulation. The parameter calculator **15** reads out a change trend of the received power of each representative terminal along with a change in base station parameters from the terminal information accumulation unit **13**. It is possible to recognize the trend by referring to the radio wave environment maps accumulated in the terminal information accumulation unit **13**. Based on the readout trend, the parameter calculator **15** calculates the received power of the representative terminal for the base station parameters set by simulation. The parameter calculator **15** calculates an SINR based on the calculated received power. Based on the calculated SINRs, the parameter calculator **15** obtains the variance of the SINRs, a lowest SINR value, an average SINR value, and a highest SINR value.

The parameter calculator **15** determines new base station parameters for the base stations **20-1** to **20-3** among the base station parameters set by simulation by referring to the obtained variance of the SINRs, lowest SINR value, average SINR value, and highest SINR value. For example, among the base station parameters set by simulation, the parameter calculator **15** determines, as new base station parameters, base station parameters with which the lowest SINR value is equal to or higher than a predetermined value (for example, 4 dB), the highest SINR value is equal to or lower than a predetermined value (for example, 37 dB), the variance of the SINRs of the respective representative terminals falls within a predetermined range, and the average SINR value is highest.

The parameter calculator **15** transmits the physical cell ID of a corresponding base station and the determined base station parameters to the parameter setting unit **16**.

The parameter setting unit **16** sets the determined base station parameters in each base station specified by the physical cell ID transmitted by the parameter calculator **15**.

An operation in which the wireless communication system with the above arrangement sets the parameters of the base stations **20-1** to **20-3** will now be described in detail. FIG. **5** is a sequence chart when the wireless communication system according to the embodiment sets the parameters of the base stations **20-1** to **20-3**.

Each of the communication terminals **30-1** to **30-3** transmits, to the base station **20-1**, the held correspondence table between the received power and the physical cell ID as terminal information together with an identifier for identifying the self-terminal (sequence S**51**). FIG. **6** is a table schematically showing an example of the correspondence table transmitted from the communication terminal to the base station, both shown in FIG. **1**.

The base station **20-1** receives the terminal information transmitted by each of the communication terminals **30-1** to **30-3**, and collects the received terminal information (sequence S**52**). Each of the base stations **20-1** to **20-3** transmits the collected terminal information to the control apparatus **10** (sequence S**53**).

The terminal information collection unit **12** of the control apparatus **10** receives the terminal information transmitted by each of the base stations **20-1** to **20-3** via the local network, and collects the received terminal information (sequence S**54**). FIG. **7** is a schematic view showing an example of the corresponding tables in the communication terminals, base stations, and control apparatus, which are shown in FIG. **1**. The terminal information collection unit **12** transmits the collected terminal information to the map generator **14** (sequence S**55**).

The map generator **14** extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other (sequence S**56**). The map generator **14** generates a radio wave environment map indicating the distribution of the representative terminals in an indoor area. FIG. **8** is a table showing the radio wave environment map generated by the map generator **14**.

Furthermore, the map generator **14** sends a radio wave environment map search request to the terminal information accumulation unit **13** to complement a representative terminal in an area where it is impossible to extract any representative terminal (sequence S**57**).

In response to the request from the map generator **14**, the terminal information accumulation unit **13** searches for a radio wave environment map similar to that generated in sequence S**56** (sequence S**58**). The terminal information accumulation unit **13** transmits the radio wave environment map similar to that generated in sequence S**56** to the map generator **14** (sequence S**59**).

The map generator **14** complements, by the radio wave environment map transmitted by the terminal information accumulation unit **13**, a representative terminal in an area where it is impossible to extract any representative terminal, thereby generating a complementary radio wave environment map (sequence S**510**). The map generator **14** transmits the generated complementary radio wave environment map to the parameter calculator **15** (sequence S**511**).

The parameter calculator **15** receives the complementary radio wave environment map transmitted by the map generator **14**, and calculates an SINR for each representative terminal of the received complementary radio wave environment map based on a received power and physical cell ID included in the representative terminal (sequence S**512**). Based on the calculated SINRs of the respective representative terminals, the parameter calculator **15** obtains the variance of the SINRs, an average SINR, a lowest SINR, and a highest SINR.

The parameter calculator **15** also sets base station parameters for the base stations **20-1** to **20-3** by simulation (sequence S**513**). The parameter calculator **15** reads out a change trend of the received power of each representative terminal along with a change in base station parameters from the terminal information accumulation unit **13** (sequence S**514**).

In response to a trend readout operation by the parameter calculator **15**, the terminal information accumulation unit **13** outputs the trend to the parameter calculator **15** (sequence S**515**).

The parameter calculator **15** inputs the trend output from the terminal information accumulation unit **13**. Based on the trend, the parameter calculator **15** calculates the received power of the representative terminal for the base station parameters set by simulation (sequence S**516**). The parameter calculator **15** calculates an SINR from the calculated received power (sequence S**517**). Based on the calculated SINRs, the parameter calculator **15** obtains the variance of the SINRs, a lowest SINR value, an average SINR value, and a highest SINR value. FIG. **9** is a table schematically showing the received power and SINR of each representative terminal when the base station parameters change, which are calculated by the parameter calculator **15**. Although **729** patterns of the base station parameters set in the base stations **20-1** to **20-3** are set in FIG. **9**, more patterns may be set.

Among the base station parameters set by simulation, the parameter calculator **15** determines new base station parameters for the base stations **20-1** to **20-3** by referring to the obtained variance of the SINRs, average SINR value, lowest SINR value, and highest SINR value (sequence S**518**). The parameter calculator **15** transmits the new base station parameters to the parameter setting unit **16** (sequence S**519**).

The parameter setting unit **16** sets the base station parameters transmitted by the parameter calculator **15** in the base stations **20-1** to **20-3** (sequence S**520**).

FIG. **10** is a schematic view showing an example of a state before the control apparatus **10** adjusts base stations **20-1** to **20-4**. FIG. **11** is a schematic view showing an example of a state after the control apparatus **10** adjusts the base stations **20-1** to **20-4**.

Referring to FIG. **10**, since a signal of a frequency F**1** transmitted by the base station **20-1** interferes with a signal of the frequency F**1** transmitted by the base station **20-2**, the communication terminal **30-1** cannot obtain enough throughput. Moreover, the communication terminal **30-2** does not belong to any communication areas formed by the base stations, and is thus located in a dead zone. Since the communication terminal **30-3** exists at the edge of the communication area formed by the base station **20-4**, it cannot obtain enough throughput. In addition, since communication terminals are densely populated around the base station **20-3** and it is thus impossible to ensure enough slots to exchange information with the communication terminals, the communication terminals located around the base station **20-3** cannot obtain enough throughput.

On the other hand, as shown in FIG. **11**, the control apparatus **10** sets the frequency of the base station **20-1** to F**2** and sets the frequency of the base station **20-3** to F**1**. This improves the throughput of the communication terminal **30-1**. The control apparatus **10** amplifies the transmission power of the base station **20-2** and that of the base station **20-4**. As a result, the dead zone where the communication terminal **30-2** is located is eliminated, and the throughput of the communication terminal **30-3** improves. Furthermore, the control apparatus **10** amplifies the transmission power of the base station **20-4**. This distributes the load of the base station **20-3** for the communication terminals, thereby improving the throughputs of the communication terminals located around the base station **20-3**.

An operation in which the wireless communication system according to the first embodiment accumulates a radio wave environment map will now be described in detail. FIG. **12** is a sequence chart showing a procedure in which the terminal information accumulation unit **13** accumulates a radio wave environment map.

Each of the communication terminals **30-1** to **30-3** transmits, to the base station **20-1**, the held correspondence table between the received power and the physical cell ID as terminal information together with an identifier for identifying the self-terminal (sequence S**121**).

The base station **20-1** receives the terminal information transmitted by each of the communication terminals **30-1** to **30-3**, and collects the received terminal information (sequence S**122**). Each of the base stations **20-1** to **20-3** transmits the collected terminal information to the control apparatus **10** (sequence S**123**).

The terminal information collection unit **12** of the control apparatus **10** receives the terminal information transmitted by each of the base stations **20-1** to **20-3**, and collects the received terminal information (sequence S**124**). The terminal information collection unit **12** transmits the collected terminal information to the map generator **14** (sequence S**125**).

The map generator **14** extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other (sequence S**126**). The map generator **14** generates a radio wave environment map indicating the distribution of the representative terminals in an indoor area (sequence S**127**). The map generator **14** transmits the generated radio wave environment map to the terminal information accumulation unit **13** (sequence S**128**).

The terminal information accumulation unit **13** receives the radio wave environment map transmitted by the map generator **14**, and accumulates the received radio wave environment map (sequence S**129**). The terminal information accumulation unit **13** also sets priority levels for the radio wave environment maps so that a radio wave environment map having a higher use frequency has a higher priority level (sequence S**1210**).

As described above, in the first embodiment, each of the base station **20-1** to **20-3** receives a received power and physical cell ID from each communication terminal **30** for wireless communication, and outputs the received power and physical cell ID to the control apparatus **10** via the local network. The control apparatus **10** clusters the received powers and physical cell IDs, and extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other, thereby generating a radio wave environment map. The control apparatus **10** accumulates the generated radio wave environment map in the terminal information accumulation unit **13**. The control apparatus **10** sets operating frequencies and transmission powers for the base stations by simulation, and empirically estimates the received powers of the representative terminals for the operating frequencies and transmission powers set by simulation, based on the past maps accumulated in the terminal information accumulation unit **13**. The control apparatus **10** determines new operating frequencies and transmission powers for the base stations **20-1** to **20-3** based on the estimation result. The control apparatus **10** sets the new operating frequencies and transmission powers. This allows the wireless communication system to dynamically improve the throughput even if a change in operation environment decreases the throughput.

According to the wireless communication system of the first embodiment, therefore, it is possible to update a radio wave environment map and dynamically adjust parameters to optimal values according to a change in operation environment.

The terminal information accumulation unit **13** sets priority levels for the accumulated past radio wave environment maps so that a radio wave environment map having a higher use frequency has a higher priority level. The terminal information accumulation unit **13** preferentially searches for a map set with a higher priority level. This enables the terminal information accumulation unit **13** to shorten the time taken to search for a radio wave environment map.

Although the map generator **14** uses a past radio wave environment map similar to the generated one to complement a representative terminal in an area where no representative terminal is extracted, the present invention is not limited to this. The map generator **14** may estimate a position where a representative terminal appears by clustering, based on a past radio wave environment map similar to the generated one. This allows the map generator **14** to shorten the time taken for clustering.

Furthermore, in the first embodiment, a case in which the parameter calculator **15** determines new base station parameters for the base stations **20-1** to **20-3** by referring to the variance of SINRs, a lowest SINR value, an average SINR value, and a highest SINR value without considering the number of communication terminals in the group has been exemplified. If, however, the number of communication terminals which are grouped into a representative terminal is equal to or larger than a specified number, an SINR calculated by the parameter calculator **15** becomes small, which increases the variance of SINRs.

To solve this problem, if the number of communication terminals which are grouped into a representative terminal is equal to or larger than the specified number, the parameter calculator **15** may widen the tolerance range of the variance of SINRs by a preset range in consideration of the number of communication terminals in the group. This enables the parameter calculator **15** to include, as candidates, base station parameters excluded from candidates in the first embodiment. That is, the parameter calculator **15** can determine base station parameters more correctly because it also considers base station parameters with a large variance of SINRs.

(Second embodiment)

FIG. **13** is a block diagram showing the functional arrangement of a wireless communication system according to the second embodiment. The wireless communication system shown in FIG. **13** includes a representative base station **40** and base stations **20-1** and **20-2**. The representative base station **40** and base stations **20-1** and **20-2** are connected to each other via a local network. Referring to FIG. **13**, the representative base station **40** accommodates communication terminals **30-1** to **30-3** for wirelessly communicating with it. Although not shown in FIG. **13**, each of the base stations **20-1** and **20-2** accommodates communication terminals for wirelessly communicating with it. The local network is connected to a core network (carrier network) via a gateway.

FIG. **14** is a block diagram showing the functional arrangement of the representative base station **40** and communication terminal **30-1**, both shown in FIG. **13**. The communication terminal **30-1** shown in FIG. **14** includes a wireless communication unit **31**, a received power information acquisition unit **32**, a received power information holding unit **33**, and a received power information notification unit **34**.

The wireless communication unit **31** wirelessly communicates with the representative base station **40** according to the LTE protocol.

The received power information acquisition unit **32** acquires the received power of a signal transmitted by each of the representative base station **40** and base stations **20-1** and **20-2**, a physical cell ID for specifying the base station which has transmitted the signal, a throughput, an error rate in communication, and sensor information such as Global Positioning System(GPS) information for specifying the position of the communication terminal at preset intervals. Note that it is possible to acquire the received power and physical cell ID in the LTE standard specification.

The received power information holding unit **33** generates and holds a correspondence table between the acquired received power and physical cell ID. The received power information holding unit **33** updates the held correspondence table every time the received power information acquisition unit **32** acquires a new received power and physical cell ID.

In response to a request from the connected representative base station **40**, the received power information notification unit **34** transmits the held correspondence table and sensor information to the representative base station **40** as terminal information. At this time, the received power information notification unit **34** transmits the terminal information added with the identifier of the self-terminal to the representative base station **40**. Note that the received power information notification unit **34** may actively transmit the terminal information to the representative base station **40** at a preset timing.

The representative base station **40** shown in FIG. **14** includes, for example, a CPU, and areas such as a ROM and RAM for storing programs and data to be used by the CPU to execute processing. The representative base station **40** includes a wireless communication unit **41**, base station controller **42**, first terminal information collection unit **43**, second terminal information collection unit **44**, terminal information accumulation unit **45**, map generator **46**, parameter calculator **47**, and parameter setting unit **48** by causing the CPU to execute programs. Note that the functional arrangement of the base station **20-1** or **20-2** shown in FIG. **14** is the same as that of the base station **20-1** described in the first embodiment.

The wireless communication unit **41** wirelessly communicates with each of the communication terminals **30-1** to **30-3**.

The base station controller **42** controls the operation of each of the base stations **20-1** and **20-2**.

The first terminal information collection unit **43** receives terminal information transmitted by each of the communication terminals **30-1** to **30-3**, and collects the received terminal information together with an identifier. When requesting terminal information of the communication terminals **30-1** to **30-3**, the first terminal information collection unit **43** may request terminal information of all the communication terminals **30-1** to **30-3**, or request terminal information of only communication terminals not in an idle state but in a connected state. The first terminal information collection unit **43** outputs the collected terminal information to the second terminal information collection unit **44**.

The second terminal information collection unit **44** collects the terminal information output from the first terminal information collection unit **43** and that transmitted by each of the base stations **20-1** and **20-2** via the local network. The second terminal information collection unit **44** transmits the collected terminal information to the map generator **46**.

The terminal information accumulation unit **45** accumulates a radio wave environment map generated by the map generator **46**. Note that the radio wave environment map will be described in conjunction with the map generator **46**.

In response to a request from the map generator **46**, the terminal information accumulation unit **45** searches accumulated past radio wave environment maps for a radio wave environment map with the distribution of representative terminals similar to that of the radio wave environment map generated by the map generator **46**. The terminal information accumulation unit **45** transmits the radio wave environment map obtained by the search processing to the map generator **46**. Note that the representative terminals will be described in conjunction with the map generator **46**, similarly to the above radio wave environment map.

Furthermore, the terminal information accumulation unit **45** sets priority levels for the accumulated radio wave environment maps so that a radio wave environment map having a higher use frequency has a higher priority level. For example, the terminal information accumulation unit **45** accumulates, for each radio wave environment map, as an index for recognizing a use frequency, the number of times the radio wave environment map is transmitted to the map generator **46**, and then sets a higher priority level for a radio wave environment map transmitted a larger number of times.

The map generator **46** extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other. The map generator **46** generates a radio wave environment map indicating the distribution of the extracted representative terminals in an indoor area. The map generator **46** transmits the generated radio wave environment map to the terminal information accumulation unit **45**.

If an area where no representative terminal is extracted since no communication terminal and thus it is impossible to acquire any terminal information, the map generator **46** complements a representative terminal in the area where no representative terminal is extracted. At this time, the map generator **46** sends a radio wave environment map search request to the terminal information accumulation unit **45**. The map generator **46** acquires one of the radio wave environment maps accumulated in the terminal information accumulation unit **45**, which has a distribution of representative terminals similar to that of the generated radio wave environment map. The map generator **46** complements, by the acquired radio wave environment map, a representative terminal in an area where no representative terminal is extracted, and generates a complementary radio wave environment map including the complemented representative terminal. The map generator **46** transmits the generated complementary radio wave environment map to the parameter calculator **47**.

Note that the map generator **46** may specify the position of each communication terminal based on sensor information such as GPS information transmitted by the communication terminal via the base station. At this time, the map generator **46** determines based on the pieces of position information whether the communication terminals are close to each other, and extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other.

Based on the complementary radio wave environment map generated by the map generator **46**, the parameter calculator **47** determines a transmission power, operating frequency, physical cell ID, neighbor list, handover threshold, base station ID, frequency bandwidth, the IP address of a base station, neighboring cell information, cell size, and the like. Note that the neighbor list, neighboring cell information, and handover threshold can form a radio wave environment in combination with the transmission power and operating frequency. That is, it is possible to control handover and generate a radio wave environment on the assumption that frequency resources are reallocated to the communication terminals in operation by intentionally changing the neighbor list and neighboring cell information in operation. Furthermore, by using the changed handover threshold, it is possible to improve the throughput by changing the connection destination of a terminal.

As a practical example, a method of determining transmission powers and operating frequencies for the base stations will be described.

The parameter calculator **47** receives the complementary radio wave environment map transmitted by the map generator **46**, and calculates an SINR for each representative terminal of the received complementary radio wave environment map based on terminal information included in the representative terminal. Furthermore, based on the calculated SINRs for the respective representative terminals, the parameter calculator **47** obtains the variance of the SINRs, a lowest SINR value, an average SINR value, and a highest SINR value.

The parameter calculator **47** sets operating frequencies and transmission powers for the base stations by simulation, and empirically estimates the received powers of the representative terminals for the operating frequencies and transmission powers set by simulation, based on the past maps accumulated in the terminal information accumulation unit **45**. The parameter calculator **47** determines new operating frequencies and transmission powers for the base stations based on the estimation result.

For example, the parameter calculator **47** sets base station parameters for the representative base station **40** and base stations **20-1** and **20-2** by simulation. The parameter calculator **47** reads out a change trend of the received power of each representative terminal along with a change in base station parameters from the terminal information accumulation unit **45**. Based on the readout trend, the parameter calculator **47** calculates the received power of the representative terminal for the base station parameters set by simulation. The parameter calculator **47** calculates an SINR from the calculated received power. Based on the calculated SINRs, the parameter calculator **47** obtains the variance of the SINRs, a lowest SINR value, an average SINR value, and a highest SINR value.

The parameter calculator **47** determines new base station parameters for the representative base station **40** and base stations **20-1** and **20-2** among the base station parameters set by simulation by referring to the obtained variance of the SINRs, lowest SINR value, average SINR value, and highest SINR value. Among the calculated base station parameters, the parameter calculator **47** determines, as new base station parameters, base station parameters with which the lowest SINR value is equal to or higher than a predetermined value (for example, 4 dB), the highest SINR value is equal to or lower than a predetermined value (for example, 37 dB), the variance of the SINRs of the respective representative terminals falls within a predetermined range, and the average SINR value is highest.

The parameter calculator **47** transmits the physical cell ID of a corresponding base station and the determined base station parameters to the parameter setting unit **48**.

The parameter setting unit **48** sets the determined base station parameters in each base station specified by the physical cell ID transmitted by the parameter calculator **47**.

An operation in which the wireless communication system with the above arrangement sets the parameters of the representative base station **40** and base stations **20-1** and **20-2** will be described in detail. FIG. **15** is a sequence chart when the wireless communication system according to the embodiment sets the parameters of the representative base station **40** and base stations **20-1** and **20-2**.

Each of the communication terminals **30-1** to **30-3** transmits, to the representative base station **40**, the held correspondence table between the received power and the physical cell ID as terminal information together with an identifier for identifying the self-terminal (sequence S**151**).

The first terminal information collection unit **43** of the representative base station **40** receives the terminal information transmitted by each of the communication terminals **30-1** to **30-3**, and collects the received terminal information (sequence S**152**). The first terminal information collection unit **43** transmits the collected terminal information to the second terminal information collection unit **44** (sequence S**153**).

The second terminal information collection unit **44** receives the terminal information transmitted by the first terminal information collection unit **43** and that transmitted by each of the base stations **20-1** and **20-2** via the local network, and collects the received terminal information (sequence S**154**). The second terminal information collection unit **44** transmits the collected terminal information to the map generator **46** (sequence S**155**).

The map generator **46** extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other (sequence S**156**). The map generator **46** generates a radio wave environment map indicating the distribution of the extracted representative terminals in an indoor area.

Furthermore, the map generator **46** sends a radio wave environment map search request to the terminal information accumulation unit **45** to complement a representative terminal in an area where it is impossible to extract any representative terminal (sequence S**157**).

In response to the request from the map generator **46**, the terminal information accumulation unit **45** searches for a radio wave environment map similar to that generated in sequence S**156** (sequence S**158**). The terminal information accumulation unit **45** transmits the radio wave environment map similar to that generated in sequence S**156** to the map generator **46** (sequence S**159**).

The map generator **46** complements, by the radio wave environment map transmitted by the terminal information accumulation unit **45**, a representative terminal in an area where it is impossible to extract any representative terminal, thereby generating a complementary radio wave environment map (sequence S**1510**). The map generator **46** transmits the generated complementary radio wave environment map to the parameter calculator **47** (sequence S**1511**).

The parameter calculator **47** receives the complementary radio wave environment map transmitted by the map generator **46**, and calculates an SINR for each representative terminal of the received complementary radio wave environment map based on a received power and physical cell ID included in the representative terminal (sequence S**1512**). Based on the calculated SINRs of the respective representative terminals, the parameter calculator **47** obtains the variance of the SINRs, an average SINR, a lowest SINR, and a highest SINR.

The parameter calculator **47** also sets base station parameters in the representative base station **40** and base stations **20-1** and **20-2** by simulation (sequence S**1513**). The parameter calculator **47** reads out a change trend of the received power of each representative terminal along with a change in base station parameters from the terminal information accumulation unit **45** (sequence S**1514**).

In response to a trend readout operation by the parameter calculator **47**, the terminal information accumulation unit **45** outputs the trend to the parameter calculator **47** (sequence S**1515**).

The parameter calculator **47** inputs the trend output from the terminal information accumulation unit **45**. Based on the trend, the parameter calculator **47** calculates the received power of the representative terminal for the base station parameters set by simulation (sequence S**1516**). The parameter calculator **47** calculates an SINR from the calculated received power (sequence S**1517**). Based on the calculated SINRs, the parameter calculator **47** obtains the variance of the SINRs, a lowest SINR value, an average SINR value, and a highest SINR value.

Among the base station parameters set by simulation, the parameter calculator **47** determines new base station parameters for the representative base station **40** and base stations **20-1** and **20-2** by referring to the obtained variance of the SINRs, average SINR value, lowest SINR value, and highest SINR value (sequence S**1518**). The parameter calculator **47** transmits the new base station parameters to the parameter setting unit **48** (sequence S**1519**).

The parameter setting unit **48** sets the base station parameters transmitted by the parameter calculator **47** in the representative base station **40** and base stations **20-1** and **20-2** (sequence S**1520**).

An operation in which the wireless communication system according to the second embodiment accumulates a radio wave environment map will now be described in detail. FIG. **17** is a sequence chart showing a procedure in which the terminal information accumulation unit **45** accumulates a radio wave environment map.

Each of the communication terminals **30-1** to **30-3** transmits, to the representative base station **40**, the held correspondence table between the received power and the physical cell ID as terminal information together with an identifier for identifying the self-terminal (sequence S**171**).

The first terminal information collection unit **43** of the representative base station **40** receives the terminal information transmitted by each of the communication terminals **30-1** to **30-3**, and collects the received terminal information (sequence S**172**). The first terminal information collection unit **43** transmits the collected terminal information to the second terminal information collection unit **44** (sequence S**173**).

The second terminal information collection unit **44** receives the terminal information transmitted by the first terminal information collection unit **43** and that transmitted by each of the base stations **20-1** and **20-2** via the local network, and collects the received terminal information (sequence **5174**). The second terminal information collection unit **44** transmits the collected terminal information to the map generator **46** (sequence S**175**).

The map generator **46** clusters the terminal information transmitted by the second terminal information collection unit **44**, and extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other (sequence S**176**). The map generator **46** generates a radio wave environment map indicating the distribution of the extracted representative terminals in an indoor area (sequence S**177**). The map generator **46** transmits the generated radio wave environment map to the terminal information accumulation unit **45** (sequence S**178**).

The terminal information accumulation unit **45** receives the radio wave environment map transmitted by the map generator **46**, and accumulates the received radio wave environment map (sequence S**179**). The terminal information accumulation unit **45** also sets priority levels for the radio wave environment maps so that a radio wave environment map having a higher use frequency has a higher priority level (sequence S**1710**).

As described above, in the second embodiment, the representative base station **40** receives a received power and physical cell ID from each communication terminal **30** for wireless communication. Each of the base stations **20-1** and **20-2** outputs the received power and physical cell ID to the representative base station **40** via the local network. The representative base station **40** clusters the received powers and physical cell IDs, and extracts a representative terminal by grouping together communication terminals which have been determined to be close to each other, thereby generating a radio wave environment map. The representative base station **40** accumulates the generated radio wave environment map in the terminal information accumulation unit **45**. The representative base station **40** sets operating frequencies and transmission powers in the base stations by simulation, and empirically estimates the received powers of the representative terminals for the operating frequencies and transmission powers set by simulation, based on the past maps accumulated in the terminal information accumulation unit **45**. The representative base station **40** determines new operating frequencies and transmission powers for the representative base station **40** and base stations **20-1** and **20-2** based on the estimation result. The representative base station **40** sets the new operating frequencies and transmission powers. This allows the wireless communication system to dynamically improve the throughput even if a change in operation environment decreases the throughput.

According to the wireless communication system of the second embodiment, therefore, it is possible to update a radio wave environment map and dynamically adjust parameters to optimal values according to a change in operation environment.

The terminal information accumulation unit **45** sets priority levels for the accumulated past radio wave environment maps so that a radio wave environment map having a higher use frequency has a higher priority level. The terminal information accumulation unit **45** preferentially searches for a map set with a higher priority level. This enables the terminal information accumulation unit **45** to shorten the time taken to search for a radio wave environment map.

Although the map generator **46** uses a past radio wave environment map similar to the generated one to complement a representative terminal in an area where no representative terminal is extracted, the present invention is not limited to this. The map generator **46** may estimate a position where a representative terminal appears by clustering, based on a past radio wave environment map similar to the generated one. This allows the map generator **46** to shorten the time taken for clustering.

Furthermore, in the second embodiment, a case in which the parameter calculator **47** determines new base station parameters for the representative base station **40** and base stations **20-1** and **20-2** by referring to the variance of SINRs, a lowest SINR value, an average SINR value, and a highest SINR value without considering the number of communication terminals in the group has been exemplified. If, however, the number of communication terminals which are grouped into a representative terminal is equal to or larger than a specified number, an SINR calculated by the parameter calculator **47** becomes small, which increases the variance of SINRs.

To solve this problem, if the number of communication terminals which are grouped into a representative terminal is equal to or larger than the specified number, the parameter calculator **47** may widen the tolerance range of the variance of SINRs by a preset range in consideration of the number of communication terminals in the group. This enables the parameter calculator **47** to include, as candidates, base station parameters excluded from candidates in the second embodiment. That is, the parameter calculator **47** can determine base station parameters more correctly because it also considers base station parameters with a large variance of SINRs.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

The invention claimed is:

1. A representative base station comprising:

a first terminal information collection unit configured to acquire and collect a received power of a signal transmitted by each of a plurality of base stations and a physical cell ID of the base station transmits the signal, which are held by a communication terminal for wirelessly communicating with the self station;

a second terminal information collection unit configured to acquire the received power and the physical cell ID which are collected by the first terminal information collection unit, and the received power and the physical cell ID which are collected by each of the plurality of base stations, and collect the acquired received powers and physical cell IDs;

a map generator configured to determine based on the collected received powers and physical cell IDs whether the communication terminals are close to each other, extract, when it is determined that communication terminals are close to each other, a representative terminal by grouping together the communication terminals which are close to each other, and generate a map indicating a distribution of the representative terminals;

a terminal information accumulation unit configured to accumulate the map generated by the map generator;

a parameter calculator configured to set operating frequencies and transmission powers for the base stations, empirically estimate, based on past maps accumulated in the terminal information accumulation unit, received powers of the representative terminals generated by the operating frequencies and transmission powers sets by simulation, and determine new operating frequencies and transmission powers for the base stations based on the estimation result; and

a parameter setting unit configured to set the new operating frequencies and transmission powers in the base stations.

2. The representative base station according to claim **1**, wherein

the terminal information accumulation unit searches for a map similar to the map generated based on the accumulated past maps, and transmits the map acquired by the search processing to the map generator, and

the map generator complements a representative terminal in an area where it is impossible to extract the representative terminal by a representative terminal included in the map transmitted by the terminal information accumulation unit.

3. The representative base station according to claim **2**, wherein the terminal information accumulation unit sets priority levels for the accumulated past maps so that a map having a higher use frequency has a higher priority level and a map having the higher priority level is preferentially selected in the search processing.

4. The representative base station according to claim **1**, wherein

the first terminal information collection unit collects sensor information for specifying a position of each of the plurality of communication terminals from the communication terminals, and

the map generator determines based on the sensor information whether the plurality of communication terminals are close to each other, and extracts, when it is determined that communication terminals are close to each other, a representative terminal by grouping together the communication terminals which are close to each other.

5. The representative base station according to claim **1**, wherein the parameter calculator sets the operating frequencies and transmission powers by simulation,

reads out a change trend of a received power of each of the representative terminals along with a change in operating frequencies and transmission powers from the accumulated past maps,

calculates the received power of the representative terminal generated by the set operating frequencies and transmission powers based on the readout trend,

calculates a Signal to Interference and Noise power Ratio(SINR) from the calculated received power, and

determines new operating frequencies and transmission powers for the base stations by referring to indices obtained by the calculated SINRs.

6. The representative base station according to claim **5**, wherein

the indices include a variance of the SINRs, a lowest SINR value, a highest SINR value, and an average SINR value which are obtained from the calculated SINRs, and among the operating frequencies and transmission powers set by simulation,

the parameter calculator determines, as new operating frequencies and transmission powers, operating frequencies and transmission powers with which the lowest SINR value is not smaller than a predetermined value, the highest SINR value is not larger than a predetermined value, the variance of the SINRs of the representative terminals falls within a predetermined range, and the average SINR value is highest.

7. The representative base station according to claim **6**, wherein if the number of communication terminals which are grouped into the representative terminal is not smaller than a specified number, the parameter calculator widens the predetermined range by a preset range.

8. A base station control method for a wireless communication system including

a plurality of base stations which are distributed and arranged in a local network and each of which wirelessly communicates with a plurality of communication terminals and acquires, from each of the plurality of communication terminals for wireless communication, a received power of a signal transmitted by each of the plurality of base stations and a physical cell ID of the base station that transmits the signal, and

a control apparatus which acquires the received powers and the physical cell IDs from the plurality of base stations, and controls the plurality of base stations based on the acquired received powers and physical cell IDs,

the method comprising:

collecting the received powers and physical cell IDs acquired from the plurality of base stations;

determining based on the collected received powers and physical cell IDs whether the communication terminals are close to each other, extracting, when it is determined that communication terminals are close to each other, a representative terminal by grouping together the communication terminals which are close to each other, and generating a map indicating a distribution of the representative terminals;

accumulating the generated map;

setting operating frequencies and transmission powers for the base stations by simulation, empirically estimating, based on accumulated past maps, received powers of the representative terminals generated by the operating frequencies and transmission powers sets by simulation, and determining new operating frequencies and transmission powers for the base stations based on the estimation result; and

setting the new operating frequencies and transmission powers in the base stations.

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